Correspondence

Tropical beetles more sensitive to impacts are less likely to be known to science

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Insects are posited to be declining globally. This is particularly pertinent in tropical forests, which exhibit both the highest levels of biodiversity and the highest rates of biodiversity loss. However, for the hyper-diverse tropical insects there are scant data available to evidence declines. Understanding tropical insect diversity and its response to environmental change has therefore become a challenge, but it is estimated that 80% of tropical insect species remain undescribed[1]. Insect biodiversity predictions are based mostly on well-studied taxa and extrapolated to other groups, but no one knows whether resilience to environmental change varies between undescribed and described species. Here, we collected staphylinid beetles from unlogged and logged tropical forests in Borneo and investigated their responses to environmental change. Out of 252 morphospecies collected, 76% were undescribed. Undescribed species showed higher community turnover, reduced abundance and decreased probability of occurrence in logged forests. Thus the unknown components of tropical insect biodiversity are likely more impacted by human-induced environmental change. If these patterns are widespread, how accurate will assessments of insect declines in the tropics be?

Environmental pressures including habitat loss and climate change can drive changes in tropical assemblages of insects[2]. This has led to some claims of a tropical 'insect apocalypse', consensus for which remains elusive owing to a lack of data. One contributing factor to this absence is the taxonomic bottleneck in describing tropical insect species. Species exhibit a set of socio-scientific attributes that can make them less likely to be described — if they belong to an unpopular group, key taxonomists don't exist or are not available or if they are from a poorly sampled region or difficult to sample. Other properties contribute to a species being undescribed, such as body size, abundance, habitat specialism and geographic range[3]. These properties are, however, also related to species' sensitivity to environmental change[4]. Accordingly, analyses examining trends in tropical insect populations may be biased towards a subset of well-studied, less sensitive species. As biodiversity indices are sensitive to taxonomic coverage and biodiversity weighting[5], this may lead to inaccurate estimations of insect declines.

Here, we test the sensitivity of described and undescribed rove beetles (Coleoptera: Staphylinidae), arguably the most species-rich and ecologically diverse animal family on Earth[6]. We collected 15,078 beetles from a total of 474 sampling points clustered within 13 blocks of unlogged (3 blocks, 81 points) and logged (10 blocks, 393 points) forests at the Stability of Altered Forest Ecosystems (SAFE) project in Sabah, Malaysian Borneo. Sampling points were separated by a minimum of 56 m and standardised for elevation (mean = 450 m, sd = 72 m) (Figure S1). At each sampling point a combined pitfall, flight-intercept and malaise trap was placed at ground level and left in place for three days. Sampling was repeated three times in February 2011, November/December 2011 and June/July 2012. Some traps were destroyed by wildlife or tree falls and some samples spoiled in storage, leading to a total final collection of N = 998 trap samples (Supplemental information) .

Of the 15,078 individuals collected, the majority belonged to the large sub-family Aleocharinae. We did not have access to the relevant taxonomic expertise to be sure that we identified all the aleocharine individuals to true species; thus they were omitted. The remaining beetles were identified to species/morpho-species by the late Mr Guillaume de Rougemont at the Oxford Museum of Natural History. De Rougemont was a coleopterist who specialised in the non-aleocharine Staphyinidae, having described over 400 new species, including 78 from Borneo. We identified 2,515 individuals representing 252 species from the remaining non-aleocharine subfamilies. Of these species only 24% were named, with 76% remaining undescribed.

All statistical analyses were carried out in R version 4.3.2[7]. Species richness was estimated 1000 times from 40 random trap samples within each sampling block to account for the different number of sampling points and traps returned from each block (40 being the lowest number returned from a single block). Estimated species richness was similar between logged (36 species) and unlogged forest (39 species) sampling blocks (Figure 1A). We calculated species turnover using the Sørensen coefficient among the pairwise logged *vs*. unlogged sampling blocks within the package 'adiv'[8]. Unnamed species in the community exhibited significantly higher turnover in comparison with named species between unlogged and logged forests (ANOVA: $F_{1,11} = 15.84$, $p < 0.01$, $R^2 = 0.41$) (Figure 1B).

For species that were present in both forest types, we calculated the difference in relative abundance of each species (the relative frequency of incidences at traps) between forest types. Named species exhibited no change in abundance between forest types, but species with reduced relative abundance were more likely to be unnamed (ANOVA: Named estimate = 0%, Unnamed estimate = -29%, $F_{1,62} = 8.19$, $p < 0.01$, $R^2 = 0.10$) (Figure 1C). Finally, we focused only on the community of beetles initially present in the unlogged forest, and tested to see if the probability of a species occurring in the logged forest varied between described and undescribed species. We fitted a generalised linear model (GLM) specifying a binomial error family. The probability of a species occurring in the logged forest was 82% for named species versus 56% for unnamed species (GLM: $Z = -2.14$, $p < 0.05$) (Figure 1D).

Overall, species more sensitive to environmental change were more likely to be undescribed. Insect declines in temperate regions have been shown to be driven predominantly by losses in abundant species, though this trend is not seen in the tropics[9]. In tropical insect samples beetles are the most abundant

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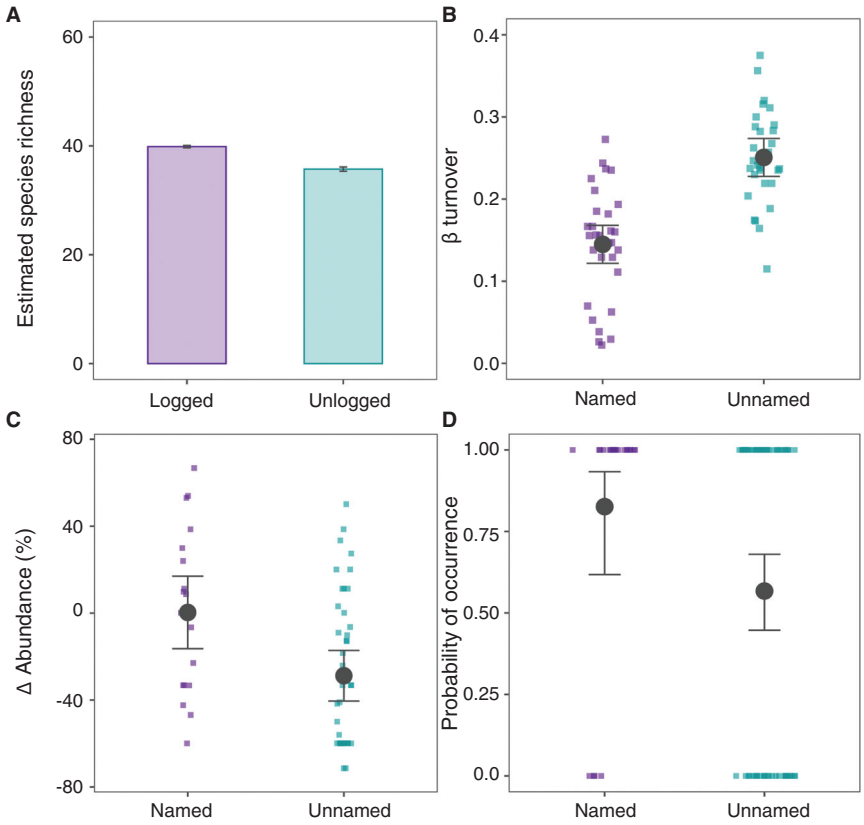

Figure 1. Responses of named and unnamed tropical staphylinid beetles to environmental change.

(A) Species richness in logged and unlogged forest blocks. Species richness was estimated 1000 times from 40 random trap samples from each block of sampling points. Estimated species richness in sampling blocks was similar between forest types (logged = 39 species, unlogged = 36 species). (B) Beta turnover of staphylinid species between unlogged and logged forest. Turnover was calculated using the Sørensen coefficient in the package 'adiv' (Pavoine, 2021). Values of 0 indicate identical communities, and values of 1 indicate communities with completely different assemblages of species. Coloured points represent pairwise comparisons between assemblages (N = 60), grey points and error bars are predicted values and 95% confidence intervals from ANOVA. Unnamed species exhibit significantly higher turnover than named species. (C) Difference in relative abundance of staphylinid species between unlogged and logged forest. Relative abundance was calculated as the relative incidence frequency of species at traps. Coloured points represent species (N = 64), grey points and error bars are predicted values and 95% confidence intervals from ANOVA. Unnamed species exhibit significantly greater negative change in relative abundance in comparison with named species. (D) Probability of persistence in logged forest. For those species that occurred in the unlogged forest, we predicted the probability of presence or absence in logged forest using a binomial GLM. Coloured points represent species (N = 90), grey points and error bars are predicted values and 95% confidence intervals from GLM. Unnamed species that occur in unlogged forest are significantly less likely to persist in logged forest in comparison with named species.

and diverse taxonomic group[10], and the staphylinids are the largest and most diverse family of beetles[6]. As 76% of staphylinid species remain undescribed at our study sites, abundant species may indeed drive declines in the tropics, but the taxonomic shortfall limits our capacity to understand tropical insect dynamics and declines.

In an age of extinction primary tropical forests represent a unique reservoir of taxonomic and functional diversity, which can act as sentinels for global biodiversity. Yet, we have only described a fraction of their resident species. Given the lack of a definitive current baseline, it may be difficult to assess accurately if tropical insects have declined. It is urgent that we achieve baselines now if we are to monitor insects in a human-dominated future.

SUPPLEMENTAL INFORMATION

Supplemental information including two figures, methods, acknowledgements, and author contributions can be found with this article online at https://doi.org/10.1016/j.cub.2024.06.059. Data used in this study are publicly available: https://zenodo.org/record/1323504

DECLARATION OF INTERESTS

The authors declare no competing interests.

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